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Wet abrasive jet machining to prepare and design the cutting edge micro shape

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Abstract

Cutting edge preparation is utilized to increase the stability of cutting tools and to improve the adhesion strength of a subsequent coating. In this context wet abrasive jet machining with a robot guided system allows to prepare local tool areas and to realize a specific design of the cutting edge, as well as advantageous surface qualities. This paper is concerned with the requirements and challenges in preparing and designing the cutting edge micro shape using wet abrasive jet machining. Important factors of the process as well as resultant shapes and topography effects of the machined cutting edges are discussed.

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Keywords: Cutting edge; geometry; surface integrity

1. Motivation and investigation approach

The preparation of cutting tool edges has proven to be very important to increase the performance of cutting tools. In literature, there are a significant number of scientific investigations analyzing the performance of prepared tools. Depending on the machining process, the process parameters, the workpiece and cutting tool material, as well as the design of the cutting edge micro shape, relating phenomena may vary [1,2,3]. In particular, the design of the cutting edge micro shape is of crucial importance for the performance of the coated cutting tool.

The micro shape and size of the prepared cutting edge represent two significant factors for the tool performance. Often a rounded shape of the cutting edge is produced, since its advantage is to affect a smoothening of micro defects along the ground surface transitions. Nevertheless, a rounded transition does not have to look like a circle so that an inclination of the transition point, towards the rake or flank face, is often defined to enhance the performance of the tool [1,4]. Besides the determination of a suitable design, one of the main challenges in this field is the reproducible realization of the micro shape at the tools' cutting edges. Content of this paper are investigations of wet abrasive jet machining as a promising and sophisticated technology for preparing cutting edge micro shapes. In particular, the handling parameters influencing the micro shape and size of the cutting edge when using a robot-guided system are analyzed.

Nomenclature

$\alpha_{jet,rel}$	relative jet inclination angle
β	wedge angle
h_d	jet nozzle distance
K	form-factor
S_γ	cutting edge segment on rake face
S_α	cutting edge segment on flank face
$\overline{S}$	average cutting edge rounding
$v_{f,jet}$	jet feed speed
R^2_{adj}	adjusted r-squared

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1.1. Wet abrasive jet machining with robot-guided systems

For cutting edge preparation wet abrasive jet machining offers a number of benefits. Investigations show that residual compressive stresses are induced in the blasted workpiece areas [5,6]. If using a robot to guide the cutting tool, the possibility to prepare cutting edges with a complex shape and of focusing locally restricted tool and edge areas need to be emphasized, too. Due to that the configuration of asymmetric micro roundings is feasible by applying this method.

Compared to dry blasting processes, further advantages can be achieved by the usage of water and abrasive suspension. Water has a damping effect which is important for the smoothening of the machined surfaces [5,7] and, in addition, helps to prevent powder accumulation [7]. Further, due to its conducting properties, thermal damages can be reduced or avoided if preparing with wet abrasive jet machining [8].

The major challenge in wet abrasive jet machining with a robot-guided systems is the complexity of process execution. In these processes, the setting of the cutting edge micro shape is attributable to a large number of interacting and influencing variables, which primarily include the jet delivery, the workpiece parameters and the cutting edge handling. The jet delivery comprises among others the jet parameters e.g. the specification of abrasive medium, the jet mass concentration, the jet pressures, the jet distribution intensity, the nozzle outlet diameter and the jet expansion angle. The workpiece parameters encompass the workpiece material specifications, the wedge angle and the initial shape of the edge [9]. The cutting edge handling parameters are discussed with in the following chapter.

1.2. Experimental setup

This work investigates the influence of cutting edge handling parameters if applying wet abrasive jet machining. Due to intended subsequent applications, such as the preparation of cutting tools with complex shaped cutting edges, as well as the accessibility of the respective cutting edges, the motion control is conducted by use of an industrial robot, shown in Figure 1. For the evaluation of the handling parameters the current workpieces are ground cemented carbide rods with five different wedge angles ($\beta = 38°$; 45°; 62.5°; 80°; 87°).

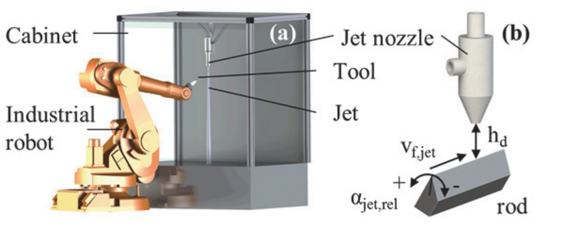

Fig. 1. (a) Wet abrasive jet machining with industrial robot; (b) cutting edge handling parameters for the robot guidance.

The cemented carbide consists of 13% cobalt and 87% tungsten carbide with a particle size of less than 0.5 µm. The workpiece is led along the cutting edge horizontally aligned under the incident jet. As schematically shown the jet feed speed $v_{f,jet}$, the jet nozzle distance h_d and the relative jet inclination angle $\alpha_{jet,rel}$ are varied. The relative jet inclination angle refers to the wedge angle's bisector crosswise to the edge. Together with the variation of the wedge angle, the findings are based on 320 experimental combinations.

The jet parameters are not varied. The jet medium is a suspension of water and abrasive material with a jet mass concentration of $\gamma_{st} \approx 10\%$. The abrasive material is new and sharp-edged aluminum oxide with a size of FEPA 220. Using a jet nozzle with an outlet diameter of $d_d = 4.5$ mm, the jet pressure at the nozzle outlet is at $p_{st} \approx 3.2$ bar.

1.3. Characteristic values of cutting edge micro shape

There are two methods that are commonly applied for measuring the size of rounded shaped cutting edges using profile sections. One is to describe the rounding size of the edge by fitting its profile sections with a circle, resulting in the cutting edge radius r_β. However, using this approach, an inclination of the profile cannot be considered. Thus there is a risk of oversimplifying the edge micro shape [7]. An alternative approach is to measure the length of the profile sections with respect to the take-off points from the rake face (S_γ) and the flank face side (S_α) towards the tip of the ideal sharp cutting edge. Both lengths are summarized by their average value to the average cutting edge rounding $\bar{S}$. The ratio of the segment on the rake face side to the flank face side results in the form-factor K, specifying the orientation of the rounding [1]. In general, a large number of profile sections are considered in both approaches to calculate average values. Values further depend on user-specified settings affecting the fitting and take-off points.

In this work $\bar{S}$ and K are utilized. Each target value has been derived from 100 profile sections, evaluated over a measuring length of 0.6 mm with the help of a digital fringe projection microscope. An illustration of measuring S_γ and S_α is shown by example of a wedge angle of $\beta = 62.5°$ in Figure 2 (a). The two other illustrations of wedge angles with $\beta = 45°$ and $\beta = 80°$ give an idea of how the wedge angle sizes affect the initial and prepared condition of cutting edges.

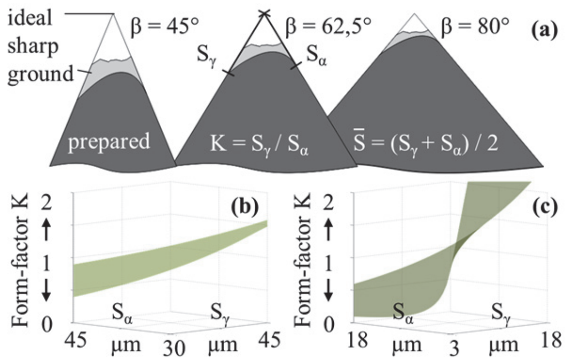

Fig. 2. (a) Cutting edge characterization; (b) achievable form-factors for $\bar{S} = 30 \ldots 45$ µm; (c) achievable form-factors for $\bar{S} = 3 \ldots 18$ µm.

In general, ground cutting edges at big wedge angles are sharp since they have fewer breakouts in the tip area. Smaller wedge angles have less material support in the tip area, thus